

Bone Metabolism on ISS Missions

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Spaceflight-induced bone loss is associated with increased bone resorption (1, 2), and either unchanged or decreased rates of bone formation. Resistive exercise had been proposed as a countermeasure, and data from bed rest supported this concept (3). An interim resistive exercise device (iRED) was flown for early ISS crews. Unfortunately, the iRED provided no greater bone protection than on missions where only aerobic and muscular endurance exercises were available (4, 5). In 2008, the Advanced Resistive Exercise Device (ARED), a more robust device with much greater resistance capability, (6, 7) was launched to the ISS. Astronauts who had access to ARED, coupled with adequate energy intake and vitamin D status, returned from ISS missions with bone mineral densities virtually unchanged from preflight (7). Bone biochemical markers showed that while the resistive exercise and adequate energy consumption did not mitigate the increased bone resorption, bone formation was increased (7, 8). The typical drop in circulating parathyroid hormone did not occur in ARED crewmembers. In 2014, an updated look at the densitometry data was published. This study confirmed the initial findings with a much larger set of data. In 42 astronauts (33 male, 9 female), the bone mineral density response to flight was the same for men and women (9), and those with access to the ARED did not have the typical decrease in bone mineral density that was observed in early ISS crewmembers with access to the iRED (**Figure 1**) (7). Biochemical markers of bone formation and resorption responded similarly in men and women.

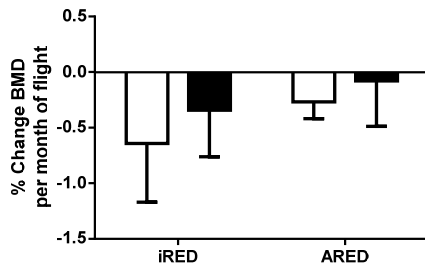


Figure 2. Bone mineral density (BMD) loss after flight in men ($n=33$, open bars) and women ($n=9$, solid bars) who used either the iRED or ARED exercise device. Data are expressed as percent change per month of flight. Figure adapted from (9).

These data are encouraging, and represent the first in-flight evidence in the history of human space flight that diet and exercise can maintain bone mineral density on long-duration missions. However, the maintenance of bone mineral density through bone remodeling, that is, increases in both resorption and formation, may yield a bone with strength characteristics different from those that existed before space flight. Studies to assess bone strength after flight are underway at NASA, to better understand the results of bone remodeling. Studies are also underway to evaluate optimized exercise protocols and nutritional countermeasures. Regardless, there is clear evidence of progress being made to protect bone during spaceflight.

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